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(54) Title: SURVIVAL DWDM SYSTEM

(57) Abstract: A traffic survival method in optical fiber telecommunication systems and in particular DWDM and having amplifi-cation sites (10) with ADD/DROP of channels and arranged between fiber spans is described and claimed. In accordance with the method the ASE noise produced in amplifiers (13) in the site is amplified in power to compensate at output the power of channels (n) lost by breakage of the site input span. An amplification device with ADD/DROP and a telecommunication system with it is also described and claimed.

SURVIVABLE DWDM SYSTEM

5 The present invention relates to an innovative method for
allowing added traffic survival in a span in optical fiber
telecommunication systems in case of link breakage in the
preceding span. The present invention also relates to a
device in accordance with said method and a telecommunica-
10 tion system provided by said method or said device.
In a WDM system with ADD/DROP optical capability a set of n
channels travels over the nth span which ends in an ampli-
fication site. In the site the signals are amplified by a
preamplifier (PA) and after attenuation caused by the
15 presence of other components such as DCF fibers or fixed or
variable attenuators et cetera it reaches an ADD/DROP
filter. Here a subset made up of 'd' channels is taken out
(DROP) and a new subset made up of 'a' channels is added
(ADD) in the system. At the ADD/DROP output there are thus
20 n-d+a channels which are amplified by a power amplifier
(booster) and moved into the following span n+1th.
In such a system the added traffic in an amplification site
must survive in case of link breakage, for example fiber
breakage in the previous span.
25 If a break occurs, for example fiber breakage in the nth
span, the n channels and consequently the removed 'd'
channels are lost but the new added channels must continue
to work without being affected by the consequences of the
breakage. This last condition is satisfied only if the

power amplifier gain remains unchanged so that the added

channels do not have to undergo power changes.

A prior art solution to the problem is to consider that

after the fiber breakage the system will have a different

5   configuration, i.e. a different number of channels, and

thus all the cards in the system must be reset in accor-

dance with the new configuration.

This requires turning off the amplifier PA and communica-

tion of the new settings to all the cards involved in the

10   transmission of the surviving channels. These cards can be

different cards of a single sub-rack but can also be cards

in other sub-racks or even in other system site. The

procedure therefore takes some time in order to inform all

the system cards about the new configuration and allow the

15   cards the time necessary for changing their settings.

During this time the system is in an uncontrolled transi-

tion situation and the added channels which must continue

to work can be influenced negatively thereby with traffic

loss.

20   If the time necessary for completion of the procedure is

longer than the traffic recovery time required by the

client this prior art solution is not feasible.

Other prior art solutions involve an additional channel

used to compensate the power of the lost channels but this

25   solution requires costly software and hardware development

from the viewpoint of development time and additional cost.

The general purpose of the present invention is to remedy

the above mentioned shortcomings by making available a

solution based on a different approach in which the ampli-

fier PA is not turned off and on the contrary is used to

compensate the power of the lost channels with no require-

ment for communication between the cards and system reset-

ting times. Another advantage of the proposed solution is

5   that it requires no particular additional hardware and

software development.

In view of this purpose it was sought to provide in accor-

dance with the present invention a traffic survival method

in optical fiber telecommunication systems and in particu-

10   lar DWDM having amplification sites with ADD/DROP of

channels arranged between fiber spans and in which the ASE

noise produced in amplifiers in the site is amplified in

power to compensate at output the power of channels lost

due to breakage of the site input span.

15   Again in accordance with the present invention it was

sought to provide an optical ADD/DROP amplification device

designed to be arranged in an amplification site between

optical fiber spans in an optical fiber telecommunication

system and comprising along the signal path between the

20   input and the output an input amplifier, an ADD/DROP device

for channels and an output amplifier characterized in that

the input amplifier has feedback which keeps the amplifier

output power virtually constant at P_{outPA} regardless of the

input signal to amplify the power of the input channels to

25   the site up to the power P_{outPA} and to amplify the power of

the ASE noise in the amplifier up to a power P_{ase} virtually

equal to the power P_{out} in case of lack of input signal in

such a manner as to compensate the power of channels lost

due to breakage of the site input span with the ASE noise.

Lastly, it was sought to provide an optical fiber telecom-
munication system comprising a plurality of amplification
sites with ADD/DROP of channels and connected together by
optical fiber spans and in which at least one site com-

5   prises a device and /or applies the above method.
To clarify the explanation of the innovative principles of
the present invention and its advantages compared with the
prior art there is described below with the aid of the
annexed drawings a possible embodiment thereof by way of

10 non-limiting example applying said principles. In the
drawings:
- FIG 1 shows a block diagram of an amplification site with
an optical fiber link entering span and an optical fiber
link emerging span, and

15 - FIG 2 shows an explanatory graph of the operating princi-
ples of the present invention.
With reference to the figures FIG 1 shows diagrammatically
an optical fiber telecommunication system with one of n
amplification sites with ADD/DROP designated as a whole by

20 reference number 20. A preceding optical fiber span 11
arrives at each site 10 and a following optical fiber span
12 emerges from each site.
The site 10 comprises an input preamplifier 13 (PA) which
receives the signal from the preceding span and sends it

25 amplified to signal treatment members 14 (DCF fibers, fixed
or variable attenuators et cetera) of the prior art and
therefore not further discussed herein. The signal then
reaches an ADD/DROP device or filter 15 where a certain
number 'd' of channels is withdrawn and a new subset made

up of a certain number 'a' of channels is added to the

system. At the ADD/DROP device output there are thus n-d+a

channels which are amplified by a power amplifier or

booster 16 (BA) and moved into the following span 12.

5   Like all the active components, the optical amplifiers are

characterized by a certain degree of noise. The main

source of noise is a spontaneous emission of the active

span of the optical amplifier which produces a random

disturbance with null mean. This noise is generally termed

10   Amplified Spontaneous Emission (ASE) noise.

In the production of optical amplifiers it is naturally

sought to keep ASE noise at negligible amounts in relation

to the signal. In normal amplifier operation i.e. with

input signal, the ASE noise therefore has power much lower

15   than the signal power. On the other hand when there is no

input in the amplifier the latter can emit only ASE noise

at output. Usually this ASE noise is not of interest and

in the prior art it is immediately eliminated by turning

off the amplifier when it receives no input signal.

20   In accordance with the innovative method of the present

invention when the amplifier receives no input, for example

because of fiber breakage of the span entering the site,

instead of suppressing the ASE noise an ASE noise with

equal power is substituted for the lacking signal power.

25   The site optical amplifiers are allowed to work with

constant output power settable by means of known electronic

control loops. The laser pumps are also controlled in a

known manner in order to hold constant the output power

without regard for the input power.

The output amplifier 16 (BA) is considered an ideal amplifier with flat gain. If we define:

P_a = power of added channels input to BA,

P_{ch} = power of N-D channels input to BA before fiber break-

5   age,

P_{ase} = power of PA ASE noise at BA input after fiber break-

age,

P_{outBA} = BA output power,

P_{outPA} = PA output power, and

10   G_1, G_2 = BA gain before and after fiber breakage,

Since it is required that the BA output power must remain

constant and equal to PoutBA, we will have:

- G1(Pch + Pa)   = PoutBA   (before fiber breakage) (1)

- G2(Pase + Pa) = PoutBA   (after fiber breakage) (2)

15   To ensure survival of the traffic of the added channels it

is necessary that their power not change after fiber break-

age. A change in the power level in the added channel

would affect its performance because of the limited dynamic

range of the system or the non-linear effects. To secure

20   this condition it is necessary to have [see equations (1)

and (2)]:

$$G1 = G2 \rightarrow P_{ase} = P_{ch}   (3)$$

Equation (3) states that the power of the ASE noise must be

equal to the power of the lost channels. Assuming that the

25   N channels are equalized in power we can write:

$$P_{ch}/P_{outPA} = (N-D)/N$$

and with equation (3) it becomes:

$$P_{ase}/P_{outPA} = (N-D)/N   (4)$$

This relationship would require a different setting between

the power of the amplifier PA before and after the fiber

breakage to control P_{outPA} e P_{ase} separately. This is not

feasible because it would require the ability of the PA to

detect a break in the fiber in the link and change its own

5   settings, thus falling back into the disadvantages of the

prior art solutions above mentioned.

For this reason the following rule is established.

$$P_{ase} = P_{outPA} \qquad\qquad (5)$$

Requiring as mentioned above that the amplifier be con-

10   trolled so as to have constant output power without concern

for the input power, equation (5) is automatically verified

because of the amplifier control loop. In other words,

when there is no input signal the amplifier increases its

power gain to amplify the internal noise until it takes its

15   own output power to the value which it was predetermined

that it should keep.

It was found that observation of equation (5) instead of

(4) provides satisfactory performance when D<<N and can

give only relatively small disadvantages when D≅N. These

20   last consist of a change in the power of the surviving

channels after fiber breakage and must be taken into

account when the flexibility of the link is appraised. But

during normal operation of the system, i.e. with no broken

fibers, the solution described adds no disadvantage since

25   the system operates indistinguishably from the conventional

system.

The output booster amplifier has a feedback for holding

output power virtually constant within a reasonable inter-

val of input power.

FIG 2 is a graph which clarifies operation of the system in accordance with the present invention by showing practical measurements on a sample system in which forty channels travel in the system and reach an ADD/DROP site. In the

5   site a channel is taken out and one is added. The spectrum shown in FIG 2 is measured after the BA output both before and after fiber breakage caused by disconnecting the PA input.

From the spectrum the profile of the ASE noise which

10   replaces the 39 channels lost after fiber breakage can be seen. It can also be seen that the surviving channel has suffered a negligible power change of <1dB which shows the effectiveness of the solution described and claimed here. It is now clear that the predetermined purposes have been

15   achieved by making available a method, device and optical fiber telecommunication system which enable excellent traffic survival in spans following a broken span. Naturally in a not ideal actual system the actual behavior of the amplifiers can add some small disadvantages, for

20   example because of the strong amplification necessary for raising the ASE noise power up to a power comparable to that of the lost channels. The impact of this on the system depends on the strength of the system, amplifier design, link configuration, architecture, channel setting

25   et cetera. An appropriate design can however minimize any disadvantages as is readily imaginable to those skilled in the art. In addition, some easy practical measurements of the actual system are sufficient to see any disadvantages introduced by application of the solution in accordance

with the present invention in the worst cases and then
consider these added disadvantages when the estimated cost
of the system is calculated.

The advantages of the solution described are in any case
5   much greater than any limited disadvantages. These limited
disadvantages can be minimized or eliminated by easy prac-
tical design choices in accordance with the normal knowl-
edge of those skilled in the art.

The solution described allows survival of added channels in
10   a DWDM system with ADD/DROP in a variety of configurations
which can be produced practically without additional hard-
ware and software development.

This makes the ADD/DROP feature available in a short time
with limited costs for a large number of system configura-
15   tions.

Naturally the above description of an embodiment applying
the innovative principles of the present invention is given
by way of non-limiting example of said principles within
the scope of the exclusive right claimed here.

20   For example the exact structure of the amplification site
can be different from that shown diagrammatically and even
comprise additional members for particular handling of the
input and output signals on the span links and the ADD/DROP
links.

CLAIMS

1. Traffic survival method in optical fiber telecommunica-
tion systems and in particular DWDM and having amplifica-
5   tion sites with ADD/DROP of channels and arranged between
fiber spans and in which the ASE noise produced in amplifi-
ers in the site is amplified in power to compensate at
output the power of channels lost by breakage of the site
input span.

10   2. Method in accordance with claim 1 in which the noise
power amplification is obtained by requiring that at least
one amplifier of the site arranged upstream of the ADD/DROP
of the channels have feedback to keep its own output power
virtually constant at a predetermined P_{outPA} value independ-
15   ently of the input signal in such a manner as to amplify
the power of the channels input to the site up to power
P_{outPA} and amplify the power of its own internal ASE noise
up to a power P_{ase} virtually equal to the power P_{outPA} if
there is no input signal.

20   3. Method in accordance with claim 1 in which an output
booster amplifier of the site is controlled to keep its own
output power virtually constant within a predetermined
input power range.

4. Optical ADD/DROP amplification device designed to be
25   arranged in an amplification site between optical fiber
spans in an optical fiber telecommunication system and
comprising along the signal path between the input and the
output an input amplifier a channel ADD/DROP device and an
output amplifier characterized in that the input amplifier

has feedback which keeps the amplifier output power virtually constant at P_{outPA} independently of the input signal to amplify the power of the channels input to the site up to the power P_{outPA} and to amplify the power of the

5   ASE noise in the amplifier up to a power P_{ase} virtually equal to the power P_{out} in case of lack of input signal in such a manner as to compensate with the output ASE noise the power of the channels lost due to breakage of the site input span.

10 5. Optical fiber telecommunication system comprising a plurality of amplification sites with ADD/DROP of channels and connected together by optical fiber spans and in which at least one site comprises a device and /or applies the method in accordance with any of the above claims.
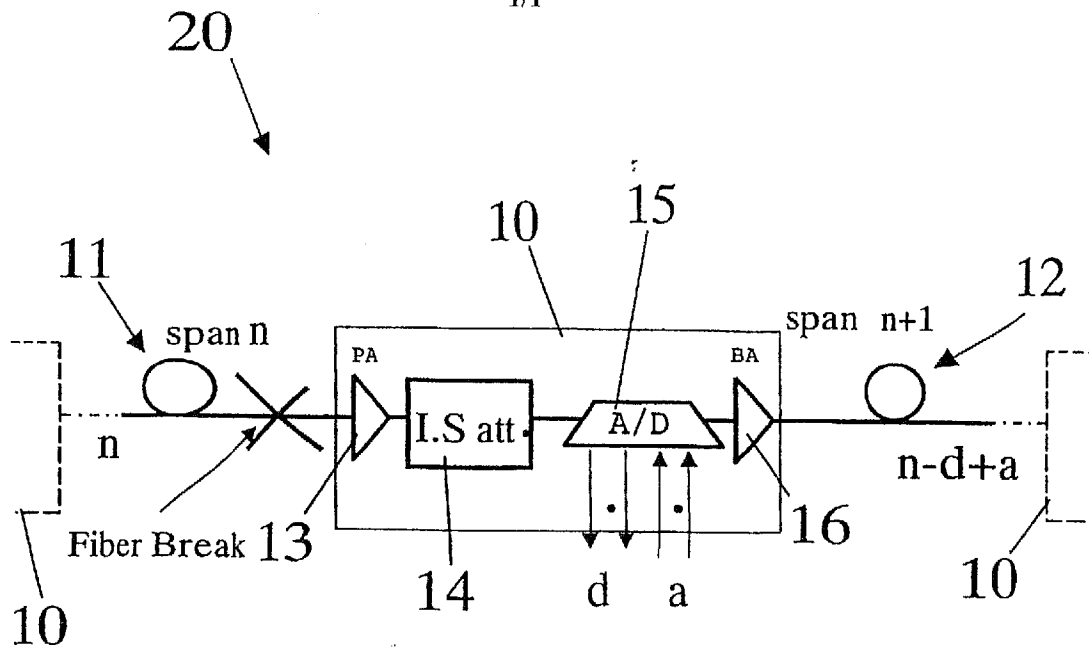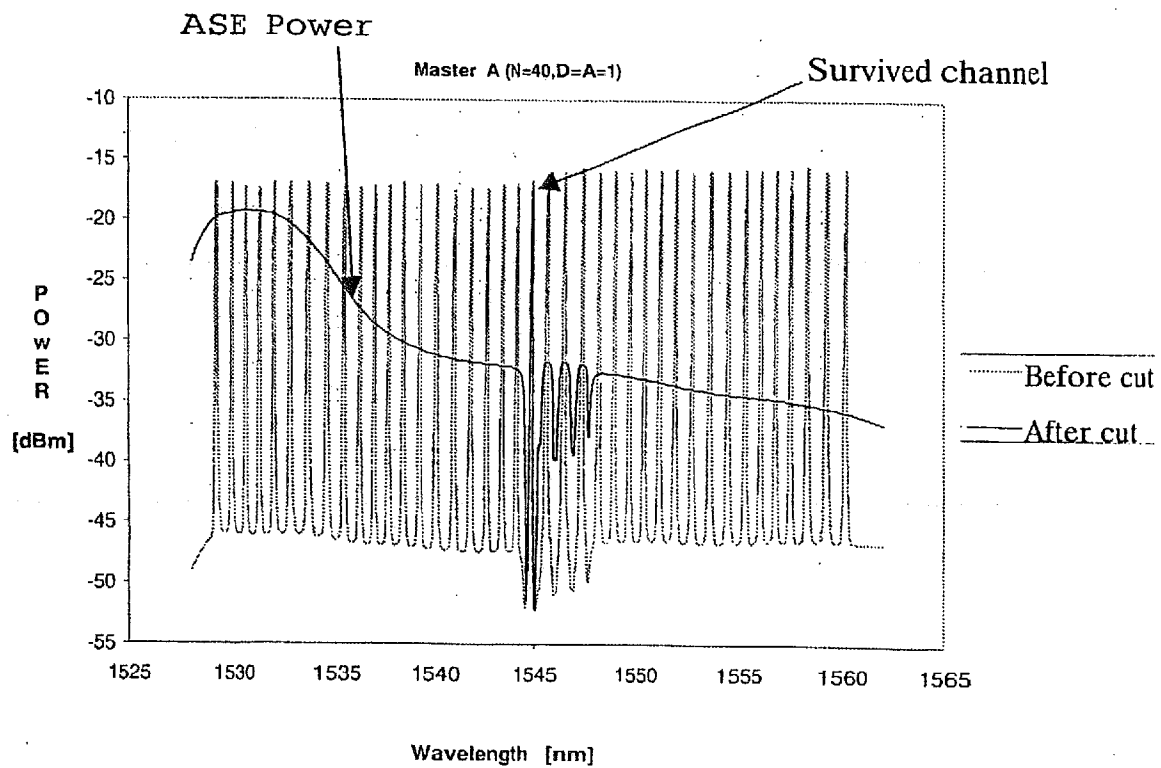
Fig. 1

Fig. 2

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04B10/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 41346 A (CORNING INC) 13 July 2000 (2000-07-13) page 9, line 24 -page 10, line 4 page 15, line 7 - line 30 figures 2,4	1-5
X	EP 0 887 955 A (LUCENT TECHNOLOGIES INC) 30 December 1998 (1998-12-30) abstract column 2, line 53 -column 3, line 3 column 6, line 1 - line 39 figures 2,5	1-5
X	US 6 043 931 A (SOULAGE GUY ET AL) 28 March 2000 (2000-03-28) column 1, line 21 -column 2, line 4 figure 1	1-5

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2002	09/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Reville, L

INTERNATIONAL SEARCH REPORT

formation on patent family members

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